SAS® Event Stream Processing Engine 2.2

Overview

SAS® Documentation

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SAS® Event Stream Processing Engine 2.2: Overview

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Contents

Using This Book

Audience

This book provides an overview to SAS Event Stream Processing Engine and describes its basic functionality. It also provides step-by-step examples that you can adapt for personal use. The intended audience is assumed to be new to the product and possibly new to SAS.

Recommended Reading

SAS Event Stream Processing Engine is supported by the following documents:

- *SAS Event Stream Processing Engine: Overview* provides an introduction to the product and an illustrative example.
- *SAS Event Stream Processing: User's Guide* describes the product and provides technical details for writing event stream processing application programs.
- Open **`$DFESP_HOME/doc/html/index.html`** in a web browser to access detailed class and method documentation for the C++ modeling, C, and Java™ client publish/subscribe APIs. The documentation is organized by modules, namespaces, and classes.

  Specifically, documentation about the following topics is provided:

  - C++ Modeling API
    - SAS Event Stream Processing API
    - SAS Event Stream Processing Connector API
  - Publish/Subscribe API
    - SAS Event Stream Processing Publish/Subscribe C API
    - SAS Event Stream Processing Publish/Subscribe Java API

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Overview to SAS Event Stream Processing Engine

Product Overview

The SAS Event Stream Processing Engine enables programmers to build applications that can quickly process and analyze volumes of continuously flowing events. Programmers can build applications with the C++ Modeling API or the XML Modeling Layer that are included with the product. Event streams are published in applications using the C or JAVA publish/subscribe APIs, connector classes, or adapter executables.

Event stream processing engines with dedicated thread pools can be embedded within new or existing applications. The XML Modeling Layer can be used to feed event stream processing engine definitions (called models) into event stream processing XML server.

Event stream processing applications typically perform real-time analytics on event streams. These streams are continuously published into an event stream processing engine. Typical use cases for event stream processing include but are not limited to the following:

- sensor data monitoring and management

- capital markets trading systems
- fraud detection and prevention
- personalized marketing
- operational systems monitoring and management
- cyber security analytics

Event stream processing enables the user to analyze continuously flowing data over long periods of time where low latency incremental results are important. Event stream processing applications can analyze millions of events per second, with latencies in the milliseconds.

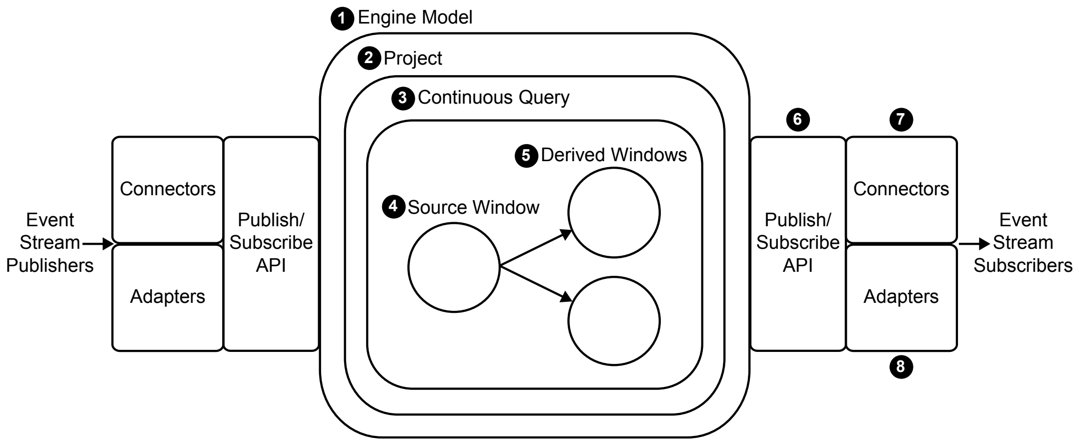
Conceptual Overview

SAS Event Stream Processing Engine enables a programmer to write event stream processing applications that continuously analyze events in motion. When designing an application, programmers must answer the following questions:

- What is the model that tells the application how to behave?
- How are event streams (data) to be published into the application?
- What transformations must occur to those event streams?
- How are the transformed event streams to be consumed?

A *model* is a user specification of how input event streams from publishers are transformed into meaningful output event streams consumed by subscribers. The following figure depicts the model hierarchy.

Figure 1.1 *Instantiation of an Engine Model*



1 At the top of the hierarchy is the *engine*. Each model contains only one engine instance with a unique name.

2 The engine contains one or more *projects*, each uniquely named. Projects contain dedicated *thread pools* that are specified relative to size. Using a pool of threads in a project enables the event stream processing engine to use multiple processor cores for more efficient parallel processing.

3 A project contains one or more *continuous queries*. A continuous query is represented by a directed graph, which is a set of connected nodes that follow a direction down one or more parallel paths. Continuous queries contain data flows, which are data transformations of incoming event streams.

4 Each query has a unique name and begins with one or more *source windows*.

5 Source windows are connected to one or more *derived windows*. Derived windows can be connected to other derived windows.

6 The *publish/subscribe API* can be used to subscribe to an event stream window either from the same machine or from another machine on the network. Similarly, the publish/subscribe API can be used to publish event streams into a running event stream processor project source window.

7 *Connectors* use the publish/subscribe API to publish or subscribe event streams to and from an engine. Connectors bypass sockets for a lower-level inject call because they are in process to the engine.

8 *Adapters* are stand-alone executable programs that can be networked. Adapters also use the publish/subscribe API.

Implementing Engine Models

SAS Event Stream Processing Engine provides two modeling APIs to implement event stream processing engine models:

- The C++ Modeling API enables you to embed an event stream processing engine inside an application process space. It also provides low-level functions that enable an application's main thread to interact directly with the engine.
- The XML Modeling Layer enables you to define single engine definitions that run like those implemented through the C++ Modeling API. You can also use it to define an engine with dynamic project creations and deletions. Also, you can use it with products such as SAS Visual Scenario Designer to perform visual modeling.

Event stream processing engine models can be embedded within application processes through the C++ Modeling API or can be XML factory servers. The application process that contains the engine can be a server shell, or it can be a working application thread that interacts with the engine threads.

The XML factory server is an engine process that accepts event stream processing definitions in one of two ways:

- in the form of a single, entire engine definition
- as create or destroy definitions within a project, which can be used to manipulate new project instantiations in an XML factory server

For either modeling layer, the decision to implement multiple projects or multiple continuous queries depends on your processing needs. For the XML factory server, multiple projects can be dynamically introduced and destroyed because the layer is being used as a service. For both modeling layers, multiple projects can be used for modularity or to obtain different threading models in a single engine instance. You can use:

- a single-threaded model for a higher level of determinism
- a multi-threaded model for a higher level of parallelism
- a mixed threading model to manipulate both

Because continuous queries can also be used a mechanism of modularity, the number of queries that you implement depends on how compartmentalized your windows are. Within a continuous query, you can instantiate and define as many windows as you need. Any given window can flow data to one or more windows, but loop-back conditions are not permitted. Event streams must be published or injected into source windows through the publish/subscribe API or through the continuous query inject method.

Within a continuous query, you can implement relational, rule-based, and procedural operators on derived windows. The relational operators include the following SQL primitives: join, copy, compute, aggregate, filter, and union. The rule-based operators perform pattern matching and enable you to define temporal event patterns. The procedural operators enable you to write event stream input handlers in C++ or DS2.

Input handlers written in DS2 can use features of the SAS Threaded Kernel library so that you can run existing SAS models in a procedural window. You can do this only when the existing model is additive in nature and can process one event at a time.

Various connectors and adapters are provided with SAS Event Stream Processing Engine, but you can write your own connector or adapter using the publish/subscribe API. Inside model definitions, you can define connector objects that can publish into source windows or that can subscribe to any window type.

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Example: Running a Continuous Query

Overview of the Example

The following example passes events through a source window and then a single filter window. Events conform to a proscribed *schema*. The schema is a structured string that defines and specifies the order of a set of variables in an event.

The following processing steps are demonstrated:

- running a simple continuous query on a published event stream
- performing a filtering computation
- determining specific events to produce in each step of processing

Here is the schema of the source window:

```
ID*: int32, symbol: string, quantity: int32, price: double
```

The filter window inherits this schema from the source window.

The schema consists of four fields:

Field	Type
ID	signed 32-bit integer
symbol	literal constant
quantity	signed 32-bit integer
price	double precision floating-point

The ID field has the * designator to indicate that this field is part of the key for the window. No other field has this designator, so the ID field completely forms the key.

Key fields are used to identify an event for operations such as Insert, Update, Delete, or Upsert. Key fields must be unique for an event. You can think of the event stream as a database and the key fields as lookup keys.

A filter expression `quantity > 1000` specifies that events are to be passed through the filter only when the **`Quantity`** field in the event exceeds the value of 1000.

Events that enter a source window must have an operation code (opcode). The opcode can be Insert (I), Update (U), Delete (D), or Upsert (P).

Opcode	Description
Insert (I)	Adds event data to a window.
Update (U)	Changes event data in a window.
Delete (D)	Removes event data from a window.
Upsert (P)	A merge function in which data for an event is updated, inserted, or both.

In the following sections, assume that an application feeds five events into the source window. The lifecycle of events is traced through the continuous query. How to run this application is described in "Building and Running the Source Code" on page 20.

Processing Events

Processing the First Event

The first event is as follows:

```
e1: [i,n,10,IBM,2000,164.1]
```

1 The source window receives `e1` as an Input event. It stores the event and passes it to the filter window.

2 The filter window receives `e1` as an Input event, as designated by the "i" in the first field. The second field in this and all subsequent events designates "normal."

3 The **`Quantity`** field has a value of 2000. Because the filter expression is `quantity > 1000`, the filter window stores the input. Typically, a filter window would pass `e1`

forward. However, because the filter window has no dependent windows, there is no additional data flow for the event.

The window contents are now as follows:

Source Window				**Filter Window**			
ID	Symbol	Qty	Price	ID	Symbol	Qty	Price
10	IBM	2000	164.1	10	IBM	2000	164.1

Processing the Second Event

The second event is as follows:

```
e2: [p,n,20,MS,1000,26.67]
```

1 The source window receives `e2` as an Upsert event. It checks whether the window has a stored event with a key (ID) of 20.

2 An ID of 20 is not stored, so the source window creates a new event `e2a: [I, 20, "MS", 1000, 26.67]`. It stores this new event and passes it to the filter window.

3 The filter window receives `e2a` as an Input event.

4 The value in the **`Quantity`** field of `e2` equals 1000, which does not meet the condition set by the filter expression in the schema. Thus, this event is not stored or passed to any dependent windows.

The window contents are now as follows:

Source Window				**Filter Window**			
ID	Symbol	Qty	Price	ID	Symbol	Qty	Price
10	IBM	2000	164.1	10	IBM	2000	164.1
20	MS	1000	26.67				

Processing the Third Event

The third event is as follows:

```
e3: [d,n,10, , , , ]
```

Note: For a Delete event, you need only specify key fields. Remember that in this example, only the ID field is key.

1 The source window receives `e3` as a Delete event.

2 The source window looks up the event that is stored with the same key. The Delete opcode removes the event from the source window.

3 The source window passes the found record to the filter window with the Delete opcode specified. In this case, the record that is passed to the filter window is as follows:

   ```
   e3a: [d,n,10,IBM,2000,164.1]
   ```

4 The filter window receives `e3a` as an Input event.

5 The value in the **`Quantity`** field of `e3a` equals 2000. This old event that was previously stored makes it through the filter, so it is removed.

The window contents are now as follows:

Source Window				**Filter Window**			
ID	Symbol	Qty	Price	ID	Symbol	Qty	Price
20	MS	1000	26.67				

Processing the Fourth Event

The fourth event is as follows:

```
e4: [u,n,20,MS,3000,26.99]
```

1 The source window receives `e4` as an Update event.

2 The source window looks up the event stored with the same key and modifies it.

3 The source window constructs an update block that consists of the new record with updated values marked as an update block followed by the old record that was updated.

4 The block is marked as a Delete event. The new event Update block that is passed to the filter window looks like this:

```
e4a: [ub,n,20,MS,3000,26.99] , [d,n,20,MS,1000,26.67]
```

Note: Both the old and new records are supplied because derived windows often require the current and previous state of an event. They need these states in order to compute any incremental change caused by an Update.

5 The filter window receives `e4a` as an Input event.

6 The value in the **`Quantity`** field of `e4a` > 1000, but previously it was <= 1000. The input did not pass the previous filter condition, but now it does pass. Because the input is not present in the filter window, the filter window generates an Insert event of the following form:

```
e4b: [i,n,20,MS,3000,26.99]
```

7 The Insert event is stored. The filter window would pass `e4b`. However, because there are no dependent windows, this input does not pass. There is no further data flow for this event.

The window contents are now as follows:

Source Window				**Filter Window**			
ID	Symbol	Qty	Price	ID	Symbol	Qty	Price
20	MS	3000	26.99	20	MS	3000	26.99

Processing the Fifth Event

The fifth event is as follows:

```
e5: [i,n,30,ACL,2000,2.11]
```

1 The source window receives `e5` as an Insert event, stores it, and passes `e1` to the filter window.

2 The filter window receives `e5` as an Input event. Because the value in the **`Quantity`** field > 1000, the filter window stores the input. Because the filter window has no dependent windows, there is no further data flow.

The window contents are now as follows:

Source Window				**Filter Window**			
ID	Symbol	Qty	Price	ID	Symbol	Qty	Price
20	MS	3000	26.99	20	MS	3000	26.99
30	ACL	2000	2.11	30	ACL	2000	2.11

C++ Code to Implement the Example

Overview to the Code

The following C++ code implements the example. You can find this code in **`$DFESP HOME/src/filter_exp`**. Edit the associated Makefile to remove the comments for architecture-specific build variables.

Create Callback Functions

Before you create the functions that process events, include header files provided with the SAS Event Stream Processing Engine modeling and execution library (for example, dfESPeventblock.h) . Then declare two callback functions, one for the source window and the other for the filter window. You register these functions with the source window and the filter window to print the events that these windows generate.

You can choose to define callback functions each window. In this example, one callback function is registered with the source window and another function is registered for the filter window. The callback for the source window receives the schema of the events that it receives and a set of one or more events bundled into a dfESPeventblock object. It also has an optional context pointer to share state across calls or to pass state into calls. The callback function for the filter window is identical to that for the source window. The callback functions are used to send a message to standard output.

```
// -*- Mode: C++; indent-tabs-mode: nil; c-basic-offset: 4 -*-
//
#include "dfESPeventblock.h"
#include "dfESPevent.h"
#include "dfESPeventdepot_mem.h"
#include "dfESPwindow_source.h"
#include "dfESPwindow_filter.h"
#include "dfESPcontquery.h"
#include "dfESPengine.h"
#include "dfESPproject.h"

using namespace std;

// Callback function for the source window.
//
void winSubscribe_source(dfESPschema *os, dfESPeventblockPtr ob,
void *context) {
     cerr << endl << "--------------------------------------------
          ----------------------" << endl;
     cerr << "sourceWindow_01" << endl;

     // The dfESPeventblock has a dump() method that prints each
     // event that the event block contains.
     ob->dump(os);
}

// Identical callback function for the filter window.
//
void winSubscribe_filter(dfESPschema *os, dfESPeventblockPtr ob,
void *context) {
     cerr << endl << "-------------------------------------------
          -----------------------" << endl;
     cerr << "filterWindow_01" << endl;
     ob->dump(os);
}
```

Create the Engine

Create the engine that sets up fundamental services such as licensing, logging, publish/subscribe, and threading.

```
// Main program - closing bracket appears at the very end of the code block
int main(int argc, char *argv[]) {

// --------- BEGIN MODEL (CONTINUOUS QUERY DEFINITIONS) ---------
// @param argc the parameter count as passed into main.
// @param argv the paramter vector as passed into main.  Currently
//     the dfESP only looks for -t <textfile.name> to write its
//     output and -b <badevent.name> to write any bad events (events
//     that failed to be applied to a window index).
// @param id the user supplied name of the engine.
// @param pubsub pub/sub enabled or disabled and port pair,
//     formed by calling static function dfESPengine::pubsubServer().
// @param logLevel the lower threshold for displayed log messages -
//     default: dfESPLLTrace, @see dfESPLoggingLevel
// @param logConfigFile a logging facility configuration file
//     - default: stdout.
// @param licKeyFile a FQPN to a license file -
//     default: $DFESP_HOME/etc/license/esp.lic
// @return the dfESPengine instance.
//
dfESPengine *myEngine = dfESPengine::initialize(argc, argv,
     "engine", pubsub_DISABLE);
 if (myEngine == NULL) {
     cerr <<"Error: dfESPengine::initialize() failed using all
     framework defaults\n";
     return 1;
}
```

Create a Project and Memory Depot

Ordinarily, engines contain one or more projects. Define the project.

```
// Define the project
dfESPproject *project_01 = myEngine->newProject("project_01");
```

Create a memory depot for the project so that it can handle the generation of primary indices and event storage.

```
// Create a memory depot
dfESPeventdepot_mem* depot_01;
depot_01 =project_01->newEventdepot_mem("memDepot_01");
```

Define a Continuous Query Object

Typically, projects contain one or more continuous queries. Define a continuous query object. This is the first-level container for source and derived windows. The object also contains window-to-window connectivity information.

```
// Create a continuous query
dfESPcontquery  *cq_01;
cq_01 = project_01->newContquery("contquery_01");
```

Build the Source and Filter Windows

Build the source window. Specify the following:

- the window name.
- the schema for events.
- the depot used to generate the index and to handle event storage.
- the type of primary index, which defines how event indexing occurs. In this case, the primary index is a hash tree.

```
// Build the source window
dfESPwindow_source *sw_01;
sw_01 = cq_01->newWindow_source("sourceWindow_01", depot_01,
dfESPindextypes::pi_HASH,
dfESPstring("ID*:int64,symbol:string,price:money,quant:int32,
vwap:double,trade_date:date,tstamp:stamp"));
```

Next, build the filter window. Specify the object name, the depot used to generate the index and to handle event storage, and the type of primary index. In this case, the primary index is a hash tree. Unlike with the source window, you do not need to specify the schema. The filter window uses the same schema as the window that provided input to it.

```
// Build a filter window
dfESPwindow_filter *fw_01;
fw_01 = cq_01->newWindow_filter("filterWindow_01", depot_01,
     dfESPindextypes::pi_HASH);
fw_01->setFilter("quant>1000");
```

Register the Filter Expression and Add Connectivity Information

Register the filter expression (quant>1000) for this window. Add the subscriber callback to the source and filter windows. These functions are called whenever a window produces output events. The events produced are both passed to these callback functions, and also sent farther down the directed graph for additional processing. Here, you format the events as CSV rows and dump them to your display. This enables you to see what each window produces at each step of the computation.

```
sw_01->addSubscriberCallback(winSubscribe_source);
fw_01->addSubscriberCallback(winSubscribe_filter);
```

Add the connectivity information to the continuous query. In this case, connect sw_01[slot 0] to fw_01.

```
cq_01->addEdge(sw_01, fw_01);
```

Start the Project and Inject Data

Define the project's thread pool size and start it. After you start the project, you do not see anything happen because no data has yet been put into the continuous query.

```
project_01->setNumThreads(1);
myEngine->startProjects();

// --------- END MODEL (CONTINUOUS QUERY DEFINITION) ---------
```

At this point, the project is running in the background using the defined thread pool. Use the main thread to inject data. In production applications, you might dedicate a thread for each active source window input event stream to optimize performance.

```
cerr <<endl <<endl;

// Declare some scratch variables to build up and submit the input
//     data.
//
dfESPptrVect<dfESPeventPtr> trans;
dfESPevent *p;
dfESPeventblockPtr ib;

//
// --------- BEGIN - DEFINE BLOCKS OF EVENTS AND INJECT into
//     running PROJECT ---------
//

cout <<endl<<endl;  // Logging uses cout as well, so just use white space
for events.
```

Build Input Data and Insert Events

Build a block of input data with three insert events. Typically, events are generated by one or more publishing applications.

```
// dfESPevent() takes the event schema and the event character string
//     where: the i is insert
//     else {u|p|d} mean update, upsert and delete respectively.
//     The n is normal.
//     The rest are the field values for the event.
//

p = new dfESPevent(sw_01->getSchema(),
     (char *)"i,n,44001,ibm,101.45,5000,100.565,2010-09-07 16:09:01,
     2010-09-07 16:09:01.123");
trans.push_back(p);

p = new dfESPevent(sw_01->getSchema(),
     (char *)"i,n,50000,sunw,23.52,100,26.3956,2010-09-08 16:09:01,
     2010-09-08 16:09:01.123");
trans.push_back(p);

p = new dfESPevent(sw_01->getSchema(),
     (char *)"i,n,66666,orcl,120.54,2000,101.342,2010-09-09 16:09:01,
     2010-09-09 16:09:01.123");
trans.push_back(p);

ib =  dfESPeventblock::newEventBlock(&trans, dfESPeventblock::ebt_TRANS);
trans.free(); // this clears the vector and frees memory
```

Inject the event block into the graph. Typically, you use the Publish and Subscribe API to subscribe to events published locally or on a networked computer system. The following `injectdata` call is a way to bypass the API and can be useful for testing.

The `injectdata` call is asynchronous with respect to processing. It deposits the input block into the queue of the source window, and then the thread pool takes over. Given this, use `quiesce()` to stop the thread until all the injected events have been processed through the entire continuous query.

```
project_01->injectData(cq_01, sw_01, ib);
project_01->quiesce(); // quiesce the graph of events

// Build & inject another block of input events, this time with updates.
//
p = new dfESPevent(sw_01->getSchema(),
     (char *)"u,n,44001,ibm,100.23,3000,100.544,2010-09-09 16:09:01,
     2010-09-09 16:09:01.123");
trans.push_back(p);

p = new dfESPevent(sw_01->getSchema(),
     (char *)"u,n,50000,sunw,125.70,3333,122.3512,2010-09-07 16:09:01,
     2010-09-07 16:09:01.123");
trans.push_back(p);

p = new dfESPevent(sw_01->getSchema(),
     (char *)"u,n,66666,orcl,99.11,954, 97.4612,2010-09-10 16:09:01,
     2010-09-10 16:09:01.123");
trans.push_back(p);

ib =  dfESPeventblock::newEventBlock(&trans, dfESPeventblock::ebt_TRANS);
trans.free();
project_01->injectData(cq_01, sw_01, ib);
project_01->quiesce(); // quiesce the graph of events
```

Build and inject another block, this time with a single delete event.

```
p = new dfESPevent(sw_01->getSchema(),
     (char *)"d,n,66666,orcl,99.11,954, 97.4612,2010-09-10 16:09:01,
     2010-09-10 16:09:01.123");
```

```
trans.push_back(p);

ib = dfESPeventblock::newEventBlock(&trans, dfESPeventblock::ebt_TRANS);
trans.free();
project_01->injectData(cq_01, sw_01, ib);
project_01->quiesce(); // quiesce the graph of events

cout <<endl<<endl;  // Logging uses cout as well, so just use white
space for events

//
// --------- END - DEFINE BLOCKS OF EVENTS AND INJECT into running
//     PROJECT ---------
```

Clean Up and Shut Down Services

Finally, clean up and shut down services.

```
myEngine->stopProjects();
myEngine->shutdown();
return 0;
}
```

Building and Running the Source Code

How to Build and Run the Source Code

Suppose that the SAS Event Stream Processing Engine library is installed in **`/opt/dfESP`**. You would enter these settings:

```
export DFESP_HOME = /opt/dfESP
export LD_LIBRARY_PATH = $DFESP_HOME/lib
```

A Perl script, **`$DFESP_HOME/bin/dfespenv`**, sets these environment variables. However, you can also add these settings to your login shell or script.

Navigate to the example directory, which is **`$DFESP HOME/src/filter_exp`**. Use the **`make`** command to build the example. In the Makefile for filter_exp, you find the following comments for the GNU Compiler Collection (GCC) on Linux:

```
# -- GCC on Linux
#    Uncomment the next three lines to use these settings.
# CXX=g++
# CXXFLAGS=-g -m64
# LDFLAGS=-L$$DFESP_HOME/lib
```

Build Results

Building the code creates an executable file that you can run. What follows depicts the results of running that executable.

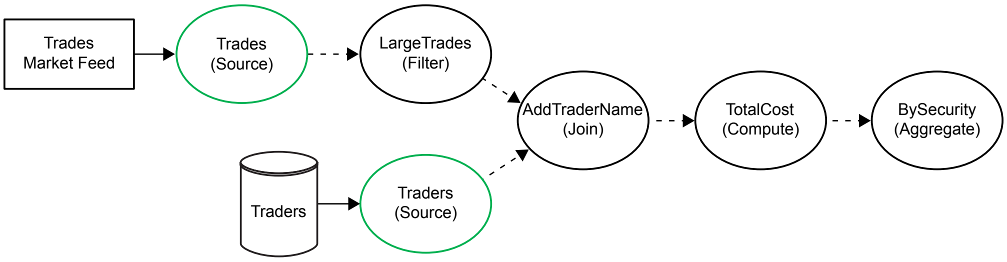
```
--------------------------------------------------------------------------------
sourceWindow_01
--------------------------------------------------------------------------------
TID: 1
depth: 1
     event[0]: <I,N: 44001,ibm,101.45,5000,100.565000,2010-09-07
     16:09:01,2010-09-07 16:09:01.123000>
     event[1]: <I,N: 50000,sunw,23.52,100,26.395600,2010-09-08
     16:09:01,2010-09-08 16:09:01.123000>
     event[2]: <I,N: 66666,orcl,120.54,2000,101.342000,2010-09-09
     16:09:01,2010-09-09 16:09:01.123000>
--------------------------------------------------------------------------------
filterWindow_01
--------------------------------------------------------------------------------
TID: 1
depth: 2
     event[0]: <I,N: 44001,ibm,101.45,5000,100.565000,2010-09-07
     16:09:01,2010-09-07 16:09:01.123000>
     event[1]: <I,N: 66666,orcl,120.54,2000,101.342000,2010-09-09
     16:09:01,2010-09-09 16:09:01.123000>
--------------------------------------------------------------------------------
sourceWindow_01
--------------------------------------------------------------------------------
TID: 2
depth: 1
     event[0]: <UB,N: 44001,ibm,100.23,3000,100.544000,2010-09-09
     16:09:01,2010-09-09 16:09:01.123000>
     event[1]: <D,N: 44001,ibm,101.45,5000,100.565000,2010-09-07
     16:09:01,2010-09-07 16:09:01.123000>
     event[2]: <UB,N: 50000,sunw,125.7,3333,122.351200,2010-09-07
     16:09:01,2010-09-07 16:09:01.123000>
     event[3]: <D,N: 50000,sunw,23.52,100,26.395600,2010-09-08
     16:09:01,2010-09-08 16:09:01.123000>
     event[4]: <UB,N: 66666,orcl,99.11,954,97.461200,2010-09-10
     16:09:01,2010-09-10 16:09:01.123000>
     event[5]: <D,N: 66666,orcl,120.54,2000,101.342000,2010-09-09
     16:09:01,2010-09-09 16:09:01.123000>
--------------------------------------------------------------------------------
filterWindow_01
--------------------------------------------------------------------------------
TID: 2
depth: 2
     event[0]: <UB,N: 44001,ibm,100.23,3000,100.544000,2010-09-09
     16:09:01,2010-09-09 16:09:01.123000>
     event[1]: <D,N: 44001,ibm,101.45,5000,100.565000,2010-09-07
     16:09:01,2010-09-07 16:09:01.123000>
     event[2]: <I,N: 50000,sunw,125.7,3333,122.351200,2010-09-07
     16:09:01,2010-09-07 16:09:01.123000>
     event[3]: <D,N: 66666,orcl,120.54,2000,101.342000,2010-09-09
     16:09:01,2010-09-09 16:09:01.123000>
--------------------------------------------------------------------------------
sourceWindow_01
--------------------------------------------------------------------------------
TID: 3
depth: 1
     event[0]: <D,N: 66666,orcl,99.11,954,97.461200,2010-09-10
     16:09:01,2010-09-10 16:09:01.123000>
```

3 Example: Processing Trades

Overview of the Example

Consider the following continuous query.

Figure 3.1 *Continuous Query Diagram*



In this continuous query, there are two source windows:

- the Trades window streams data about securities transactions from a trades market feed

- The Traders window streams data about who performs those transactions. This data could be published from a file, a database, or some other source.

As the source windows get data, the following occurs:

1 The Trades source window flows into the LargeTrades derived window, which filters out transactions that involve fewer than a defined number of shares.

2 LargeTrades and Traders flow into the join window named AddTraderName. This window matches filtered transactions with their associated traders.

3 Events from AddTraderName flow into the compute window named TotalCost, where the cost of the transaction is calculated.

4 Events are passed on to the aggregate window BySecurity, where they are placed into aggregate groups.

C++ Code for Processing Trades

The following C++ program implements the model. The program follows these steps.

1 Include needed header files from the SAS Event Stream Processing Engine library so that you can use the appropriate objects to define elements of the model.

2 After the main declaration, define objects for the engine, the project, the event depot, and the continuous query.

3 Set the date format for the engine.

4 Define the Trades and Traders source windows.

5 Define the LargeTrades filter window.

6 Define the AddTraderName join window. Specify the join conditions.

7 Define the TotalCost compute window.

8 Define the AddSecurity aggregate window.

9 Set the number of threads for the engine. Run the project. Shut down the engine.

```
#include "dfESPengine.h"
#include "dfESPeventdepot_mem.h"
#include "dfESPwindow_source.h"
#include "dfESPwindow_aggregate.h"
#include "dfESPwindow_filter.h"
#include "dfESPwindow_join.h"
#include "dfESPwindow_compute.h"
#include "dfESPcontquery.h"
#include "dfESPproject.h"

int main(int argc, char *argv[]) {

    dfESPengine        *theEngine
    =    dfESPengine::initialize(argc, argv, "theEngine", pubsub_DISABLE);
    dfESPproject    *project_01
    =    theEngine->newProject("project_01");
    dfESPeventdepot_mem    *mem_01
    =    project_01->newEventdepot_mem("mem_01");
    dfESPcontquery    *cq_01
    =    project_01->newContquery("cq_01");

    theEngine->set_dateFormat((char *)"%d/%b/%Y:%H:%M:%S");

    dfESPwindow_source    *Trades
    =    cq_01->newWindow_source("Trades", mem_01, dfESPindextypes::pi_HASH,
              dfESPstring("tradeID*:string,security:string,quantity:int32,
                           price:double,traderID:int64,time:stamp"));

    dfESPwindow_source    *Traders
    =    cq_01->newWindow_source("Traders", mem_01,
                                 dfESPindextypes::pi_HASH,
                                 dfESPstring("ID*:int64,name:string"));

    dfESPwindow_filter    *LargeTrades
    =    cq_01->newWindow_filter("LargeTrades", mem_01,
                                 dfESPindextypes::pi_RBTREE);
    LargeTrades->setFilter("quantity>=100");

    dfESPwindow_join    *AddTraderName
    =    cq_01->newWindow_join("AddTraderName", dfESPwindow_join::jt_LEFTOUTER,
                             mem_01, dfESPindextypes::pi_RBTREE);
    AddTraderName->setJoinConditions("l_traderID==r_ID");
    AddTraderName->setJoinSelections("l_security,l_quantity,l_price,l_traderID,
                                l_time,r_name");
    AddTraderName->setFieldSignatures("security:string,quantity:int32,price:double,
                                 traderID:int64,time:stamp,name:string");

    dfESPwindow_compute    *TotalCost
    =cq_01->newWindow_compute("TotalCost", mem_01,
                            dfESPindextypes::pi_RBTREE,
    dfESPstring("tradeID*:string,security:string,quantity:int32,
                 price:double,totalCost:double,traderID:int64,time:stamp,
                 name:string"));
    TotalCost->addNonKeyFieldCalc("security");
    TotalCost->addNonKeyFieldCalc("quantity");
    TotalCost->addNonKeyFieldCalc("price");
    TotalCost->addNonKeyFieldCalc("price*quantity");
    TotalCost->addNonKeyFieldCalc("traderID");
    TotalCost->addNonKeyFieldCalc("time");
    TotalCost->addNonKeyFieldCalc("name");

    dfESPwindow_aggregate    *BySecurity
     = cq_01->newWindow_aggregate("BySecurity", mem_01, dfESPindextypes::pi_RBTREE,
                                dfESPstring("security*:string,quantityTotal:double,
                                             costTotal:double"));
    BySecurity->addNonKeyFieldCalc("ESP_aSum(quantity)");
    BySecurity->addNonKeyFieldCalc("ESP_aSum(totalCost)");

    cq_01->addEdge(Trades, 0, LargeTrades);
    cq_01->addEdge(LargeTrades, 0, AddTraderName);
    cq_01->addEdge(Traders, 0, AddTraderName);
    cq_01->addEdge(AddTraderName, 0, TotalCost);
    cq_01->addEdge(TotalCost, 0, BySecurity);

    project_01->setNumThreads(1);
    theEngine->startProjects();

    dfESPengine::shutdown();

    return 0;
}
```

XML Code for Processing Trades

The following code renders the model in the SAS Event Stream Processing Engine XML modeling language:

```
<engine port='55555' dateformat='%d/%b/%Y:%H:%M:%S' trace='false'>
    <projects>
        <project name='trades_proj' pubsub='auto' threads='4'>
            <contqueries>
                <contquery name='trades_cq'>
                    <windows>
                        <window-source name='Trades'
                         index='pi_RBTREE' id='Trades_0001'>
                            <schema>
                                <fields>
                                    <field name='tradeID' type='string' key='true'/>
                                    <field name='security' type='string'/>
                                    <field name='quantity' type='int32'/>
                                    <field name='price' type='double'/>
                                    <field name='traderID' type='int64'/>
                                    <field name='time' type='stamp'/>
                                </fields>
                            </schema>
                        </window-source>

                        <window-source name='Traders' id='Traders_0002'>
                            <schema>
                                <fields>
                                    <field name='ID' type='int64' key='true'/>
                                    <field name='name' type='string'/>
                                </fields>
                            </schema>
                        </window-source>

                        <window-filter name='LargeTrades' id='LargeTrades_0003'>
                            <expression>quantity >= 100</expression>
                        </window-filter>

                        <window-join name='AddTraderName' id='AddTraderName_0004'>
                            <join type="leftouter" left="LargeTrades_0003"
                                  right='Traders_0002' >
                                <conditions>
                                  <fields left='traderID' right='ID' />
                                </conditions>
                            </join>
                            <output>
                                <field-selection name='security' source='l_security'/>
                                <field-selection name='quantity' source='l_quantity'/>
                                <field-selection name='price' source='l_price'/>
                                <field-selection name='traderID' source='l_traderID'/>
                                <field-selection name='time' source='l_time'/>
                                <field-selection name='name' source='r_name'/>
                            </output>
                        </window-join>

                        <window-compute name='TotalCost' id='TotalCost_0005'>
                            <schema>
                                <fields>
                                    <field name='tradeID' type='string' key='true'/>
                                <!-- These are the non-key fields -->
                                    <field name='security' type='string'/>
                                    <field name='quantity' type='int32'/>
                                    <field name='price' type='double'/>
                                    <field name='totalCost' type='double' />
                                    <field name='traderID' type='int64'/>
                                    <field name='time' type='stamp'/>
                                    <field name='name' type='string' />
                                </fields>
                            </schema>
                            <!-- These are how the non-key fields are computed-->
                            <output>
                                <field-expr>security</field-expr>
                                <field-expr>quantity</field-expr>
                                <field-expr>price</field-expr>
                                <field-expr>price*quantity</field-expr>
                                <field-expr>traderID</field-expr>
                                <field-expr>time</field-expr>
                                <field-expr>name</field-expr>
                            </output>
                        </window-compute>

                        <window-aggregate name='BySecurity' id='BySecurity_0006'>
                            <schema>
                                <fields>
                                    <field name='security' type='string' key='true'/>
                                    <field name='quantityTotal' type='double'/>
                                    <field name='costTotal' type='double'/>
                                </fields>
                            </schema>
                            <output>
```

```
                                <field-expr>ESP_aSum(quantity)</field-expr>
                                <field-expr>ESP_aSum(totalCost)</field-expr>
                            </output>
                        </window-aggregate>
                    </windows>

                    <edges>
                        <!-- Traders -> AddTraderName -->
                        <edge source='Traders_0002' target='AddTraderName_0004'/>

                        <!-- Trades -> LargeTrades -> AddTraderName ->
                             TotalCost -> BySecurity -->
                        <edge source='Trades_0001' target='LargeTrades_0003'/>
                        <edge source='LargeTrades_0003' target='AddTraderName_0004'/>
                        <edge source='AddTraderName_0004' target='TotalCost_0005'/>
                        <edge source='TotalCost_0005' target='BySecurity_0006'/>
                    </edges>

                </contquery>
            </contqueries>
        </project>
    </projects>
</engine>
```

Running the XML Code

Here are the steps to run the XML code on Unix-like platforms.

1 Execute the event streams processing XML factory server with the model:

$DFESP_HOME/bin/dfesp_xml_server -model file://*full_path_to_xmlfile* – messages *full_path_to_messages*.

2 Use **dfesp_fs_adapter** to populate the traders window with the events in the traders.csv file. The traders.csv file contains the input events for the Traders window.

$DFESP_HOME/bin/dfesp_fs_adapter -k pub -h dfESP://localhost:55555/trades_proj/trades_cq/Traders -f traders.csv -t csv -b 256.

3 Subscribe to the final BySecurity window to see the computed data when the trades data starts flowing:

```
$DFESP_HOME/bin/dfesp_streamviewer "dfESP://localhost:55555/
trades_proj/trades_cq/BySecurity"
```

4 Use `dfesp_fs_adapter` to publish trades data from the trades.csv file. The trades.csv file contains the input events for the Trades window.

```
$DFESP_HOME/bin/dfesp_fs_adapter -k pub -h dfESP://localhost:
55555/trades_proj/trades_cq/Trades -f trades.csv -t csv -b 256
-d %d/%b/%Y:%H:%M:%S
```

Here are the steps to run the XML code on a Microsoft Windows 64 platform.

1 Execute the event stream processing XML factory server with the trades model:

```
%DFESP_HOME%\bin\dfesp_xml_server.exe -model file://
full_path_to_trades –messages full_path_to_messages
```

2 Use `dfesp_fs_adapter` to populate the traders window with the events in the traders.csv file. The traders.csv file contains the input events for the Traders window.

```
%DFESP_HOME%\bin\dfesp_fs_adapter.exe -k pub -h dfESP://
localhost:55555/trades_proj/trades_cq/Traders -f traders.csv -
t csv -b 256
```

3 Subscribe to the final BySecurity window to see the computed data when the trades data starts flowing:

```
%DFESP_HOME%\bin\dfesp_streamviewer.bat "dfESP://localhost:
55555/trades_proj/trades_cq/BySecurity"
```

4 Use `dfesp_fs_adapter` to publish trades data from the trades.csv file. The trades.csv file contains the input events for the Trades window.

```
%DFESP_HOME%\bin\dfesp_fs_adapter.exe -k pub -h dfESP://
localhost:55555/trades_proj/trades_cq/Trades -f trades.csv -t
csv -b 256 -d %d/%b/%Y:%H:%M:%S
```

Glossary

derived windows
windows that display events that have been fed through other windows and that perform computations or transformations on these incoming events.

directed graph
a set of nodes connected by edges, where the edges have a direction associated with them.

engine
the top-level container in a model. The engine manages the project resources.

event block
a grouping or package of events.

event stream processing
a process that enables real-time decision making by continuously analyzing large volumes of data as it is received.

event streams
a continuous flow of events (or more precisely, event blocks).

factory server
a server for factory objects that control the creation of other objects, access to other objects, or both. A factory object has a method for every object that it can create.

memory depot
a repository for indexes and event data that is used by a project.

modeling API

an application programming interface that enables developers to write event stream processing models.

operation code (opcode)

an instruction that specifies an action to be performed.

publish/subscribe API

a library that enables you to publish event streams into an event stream processor, or to subscribe to event streams, within the event stream processing model. The publish/subscribe API also includes a C and JAVA event stream processing object support library.

source window

a window that has no windows feeding into it and is the entry point for publishing events into the continuous query.

stream

a sequence of data elements made available over time.

thread pool

a set of threads that can be used to execute tasks, post work items, process asynchronous I/O, wait on behalf of other threads, and process timers.

window

a processing node in an event stream processing model. Windows in a continuous query can perform aggregations, computations, pattern-matching, and other operations.